253860-1-X (R)

SATELLITE DIRECT READOUT: OPPORTUNITIES FOR SCIENCE EDUCATION

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February 1994

Submitted to:
Defense Technical Information Center
Cameron Station, Room 5B205
Alexandria, VA 22314

42 pgs

Attn: Dr. Forrest R. Frank

Contract Number: DLA900-88-D-0392 D.O. #0054

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Ann Arbor, MI 48113-4001

ERIM-320

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1994	Technical,

4. TITLE AND SUBTITLE

Satellite Direct Readout: Opportunities for Science Education

5. FUNDING NUMBERS

6. AUTHOR(S)

Thomas W. Wagner

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Environmental Research Institute of Michigan
P.O. Box 134001
Ann Arbor, MI 48113-4001

8. PERFORMING ORGANIZATION REPORT NUMBER

253860-1-X (R)

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Defense Technical Information Center
Cameron Station, Room 5B205
Alexandria, VA 22314

Attn: Dr. Forrest R. Frank

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

DLA900-88-D-0392

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

This report describes the technology associated with direct reception and analysis of environmental (weather) satellite data and the opportunities it offers to educators for enhancing mathematics, science, and technology education in the United States. With newly available capabilities, direct readout is applicable to a wide range of environmental assessments, information networking, and modelling applications, in addition to the learning opportunities in K-16 education. This report describes the institutional, technical, and pedagogical obstacles to widespread use of this technology and suggests approaches to overcoming these obstacles.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Education, Direct readout, APT, WEFAX, Science	41
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-92)
Prescribed by ANSI Std. 239-18
298-102

ERIM

Satellite Direct Readout: Opportunities for Science Education

FOREWORD

This report was prepared by the Environmental Research Institute of Michigan (ERIM) under contract DLA 900-88-D-0392 from the Defense Technical Information Center. Under this contract ERIM provides technical support to the Department of Defense (DoD) through its Infra Red Information Analysis (IRIA) Center.

This report describes the technology associated with direct reception and analysis of environmental (weather) satellite data and the opportunities it offers to educators for enhancing mathematics, science, and technology education in the United States. With newly available capabilities, direct readout is applicable to a wide range of environmental assessments, information networking, and modelling applications, in addition to the learning opportunities in K-16 education. This report describes the institutional, technical, and pedagogical obstacles to widespread use of this technology and suggests approaches to overcoming these obstacles.

Dr. Forrest Frank, Program Manager, Information Analysis Centers, Defense Technical Information Center and Rodney C. Anderson, Director of IRIA provided technical direction for this program. Cindy Wiles of ERIM's Washington Office provides ongoing liaison with the sponsor. In preparing this report, Thomas W. Wagner*, wishes to acknowledge the assistance of ERIM colleagues Suzanne Czurylo, Peter Tchoryk, Cyrus Wood, and Dale Faye, however he alone is responsible for its contents.

* ERIM Manager, NASA-supported Space Technology Education Program (STEP).

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1.0 Introduction

Increasing numbers of teachers are installing satellite direct readout stations in their classrooms to stimulate student interest in math, science, geography, technology, and a range of other subjects. Data from environmental satellites of the United States, Europe, Japan, and Russia provide opportunities for students to engage in real-world applications for understanding earth systems processes.

1.1 This Report

This report supports the Defense Technical Information Center's (DTIC) "Environmental Data Collection and Information Analysis Tools Enhancement" task (see Table 1) in discussing satellite direct readout technology for K-16 education in this country. In non-technical terms, it describes the design and operation of direct readout technology for obtaining environmental data, and how such systems can contribute to science, math, and technology education in this country.

Table 1. Summary Statement of Work

1. Develop and implement a protocol for the collection and analysis of PC-based satellite direct readout ground station. The purpose...is to assess obstacles to the use of direct readout ground station data in a variety of educational contexts.

2. Acquire, configure, and install one PC-based satellite direct readout ground station...that can be use to apply analytical techniques at IRIA in domains beyond those originally in tended.

3. Modify existing ground station software as necessary to develop alternative methods to display and utilize direct readout environmental information and conduct off-site demonstra tions/field trials of the technology.

4. Identify additional modifications to software, data conversion, data communication, and other system elements to facilitate use of PC-based satellite direct readout environmental information as part of the DoD Distributed Interactive Simulation program.

This report is comprised of five sections. Section 1 describes direct readout, its alternatives and constraints, in a question and answer format. Section 2 summarizes the uses of direct readout in education, with emphasis on newly emerging national Science Education Standards. Section 3 provides the specifications of the portable ERIM Direct Readout station assembled for this task. Section 4 describes station enhancements to increase the utility of direct readout for education; and Section 5 suggests several specific actions that could lead to greater use of direct readout for K-16 education and other applications.

1.2 Introducing Direct Readout

What is Direct Readout?

Satellite direct readout is the technical process of receiving data directly from artificial satellites and the scientific process of obtaining information from these data.

As indicated by its name, direct readout captures "live" data from satellites without the use of intermediate ground-based reception or transmission facilities. From a practical standpoint direct readout usually refers to the reception and processing of image data from earth-orbiting environmental (weather) satellites.

Whose satellites provide these data?

Environmental (weather) satellites of the United States, Europe, Japan, and Russia provide direct readout services to users on the ground. In the United States, the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce manages its direct readout satellites. In the past, China has also provided direct readout satellite data, but none of the Chinese satellites are now working.

In what form are these data broadcast?

Two general types of direct readout data are broadcast: (1) low resolution, analog APT (Automatic Picture Transmission) and WEFAX (Weather Facsimile) and (2) high resolution, digital HRPT (High Resolution Picture Transmission). For this report we are concerned with the low resolution APT and WEFAX data because of its suitability for education.

APT data are transmitted in the 137-138 MHz (VHF) waveband and WEFAX data are transmitted at 1691.0 MHz. The higher frequency WEFAX data are usually downconverted to 137.5 MHz so that they may be received by the same equipment used for receiving the APT data.

What's' the difference between "direct readout" and "direct broadcast" ?

Unlike direct broadcast satellites, direct readout satellites originate the data they transmit to the ground. "Direct broadcast" is a term commonly used with TV-communication satellites and many schools have antennas to receive educational programs from direct broadcast satellites. The electronics of these antennas are not the same as for obtaining from direct readout satellite data; a separate antenna is required.

What's the difference between APT and WEFAX data?

Automatic Picture Transmission (APT) data are broadcast by satellites in near polar or "sun-synchronous" earth orbits. Currently four U.S. and at least four Russian environmental satellites transmit APT data. These satellites travel in north-south or south-north directions (nearly over the poles) at approximately 830 kilometers (500 miles) above the earth. They orbit the earth once every 102 minutes and move 15 degrees to the West with each pass so that the same location on the ground is covered twice each day (once during daylight and once at night). APT data are transmitted at the same time that the satellite collects the data -- it's "real time".

Weather Facsimile (WEFAX) data are broadcast by so-called "geostationary" or "geosychronous" satellites. These satellites are 33,500 kilometers above the equator. They orbit the earth at the same rate and in the same direction that the earth rotates. Thus the satellite appears to remain stationary with respect to the earth's surface, i.e. the same hemisphere is continuously in view. Data obtained by these satellites are first transmitted to a station on the ground, where they are geometrically corrected and overlaid with a map. Then the data are sent back to the satellite for retransmission to stations on the ground. With delays up to an hour, these data are "near real time".

Two geostationary satellites, the European Meteosat-3 and the U.S. GOES-West, operate over different parts of the Western Hemisphere. However, a new U.S. satellite, GOES-Next, is expected to be launched in late 1994. Another European Meteosat covers Europe and Africa and a Japanese satellite (GMS) covers East Asia and the South Pacific. An Indian geostationary satellite (INSAT) covers Central and South Asia but data from INSAT are not available by direct readout.

What is the smallest distinguishable feature that may seen on an APT or WEFAX image?

The spatial resolution is approximately four kilometers at nadir, decreasing to seven kilometers at the scene edges, for the APT images (slightly greater for the Russian satellite data). It is eight kilometers at nadir for the WEFAX images if full resolution obtained. Sometimes the WEFAX images are subsampled to show larger areas at much lower resolutions.

How much area does each image cover?

An APT image shows a N-S swath almost 3000 kilometers wide. The length of the image depends on the location of the ground station with respect to the satellite. If the satellite passes directly over the station, approximately 5000 kilometers of data in a north-south direction may be obtained — equivalent to the distance from Hudson's Bay in Canada to Jamaica in the Caribbean. Less area is covered during a side-pass.

At 33,500 kilometers above the earth, WEFAX satellites observe and record entire hemispheres. Operationally these hemispherical views are divided into four or six segments that are broadcast individually at regular (approximatelly hourly) intervals. Thus one can "tune in" at a predetermined time to get new pictures of North America, the Caribbean, or Brazil. Each segment covers an area of over 35 degrees of longitude and latitude.

How many images are available to stations in the United States each day?

Over 300 individual APT and WEFAX images are broadcast every day within range of U.S.-based stations. At full resolution, each of these images may be recorded in digital files that range from 250 kilobytes to over 2 megabytes. That's a lot of data. From a practical standpoint, users make decisions on what data to collect and when. These decisions are based on the equipment and time available and the uses to be made of the data. For the classroom, often the scheduled hourly WEFAX data is more practical than the advance planning necessary for getting APT data.

What does it cost to receive these data?

This is the beauty of direct readout — this flood of live satellite data is free. No fees, other costs, licensing or official approvals are required. The data are considered a public good. After the initial station investment, there are no recurring costs (other than for system operation and maintenance).

What does a direct readout station cost?

An initial investment of between $3000 and $6000 will provide the equipment and software required for a functional direct readout station. All of the equipment components are commercially available and several vendors supply turn-key systems. Perhaps 40 hours or so are required for the assembly, setup, and testing of a new direct readout station. The hardest part of assembly is the placement of the exterior antenna(s). If a satellite dish is setup, advance approval of a local zoning board may be required.

What are the components of a direct readout station?

A direct readout station consists of one or two inexpensive antennas (usually a TV-style, omni-directional antenna for the polar orbiters and a 4-6 ft. parabolic dish for WEFAX), a scan decoder and radio receiver linked to a personal computer with a high resolution monitor and display software (Figure 1). The radio receiver and scan decoder may be separate units external to the computer or they may be in the computer. Most PCs with a 80286 (10 MHz) microprocessor or faster are suitable for receiving and processing satellite images. A larger hard disk for saving image files is strongly recommended. Ancillary components, such as printers, modems, and CD-ROMs, are useful but not absolutely essential.

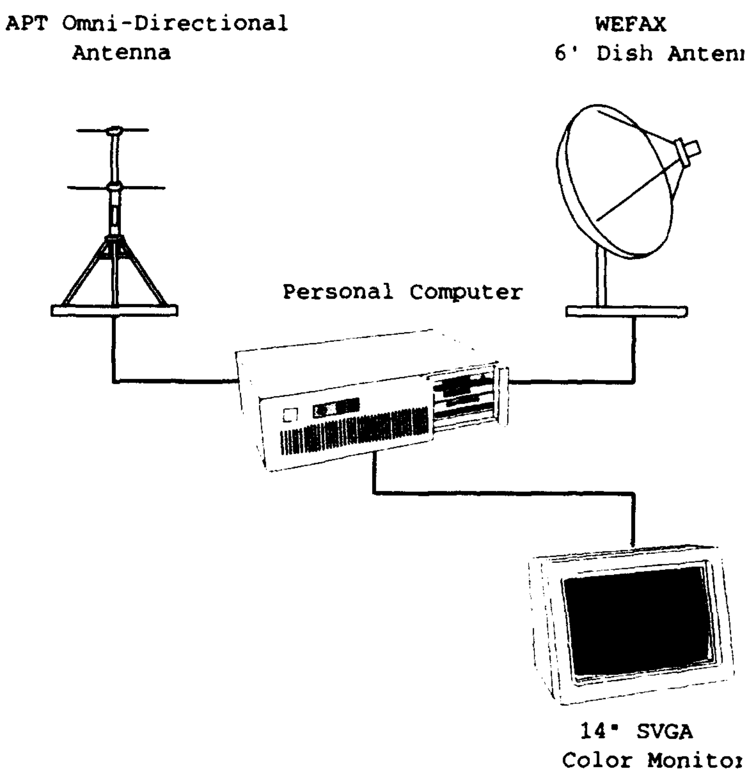

Figure 1. Components of a Direct Readout Station:

1. APT antenna and/or a WEFAX antenna
   with downconverter
2. VHF 137 MHz receiver (external or internal to the computer)
3. 286 personal computer or better (including display hardware and software)
   and a high-resolution (SVGA) monitor
4. useful options: a modem, a printer, a CD-ROM.

What kinds of images may be received by direct readout?

For U.S. NOAA satellites, both visible and infrared images are obtained "live" while the satellite traverses the sunlit portion of the earth. While the satellite traverses the shadowed (night) portion of each orbit, only thermal images are transmitted. With the thermal images from the U.S. satellites, temperature calibration information is also included.

For WEFAX, visible, thermal, and "water vapor" images are transmitted on a scheduled basis. Thermal images are collected roughly hourly, day and night, and visible images are collected hourly during the day. The lower resolution water vapor images are obtained every three hours.

Besides image data, what other types of data are available from direct readout?

The U.S. GOES rebroadcasts images obtained by other satellites showing other areas of the world, such as East Asia and Oceania, and various weather maps showing winds, air pressures, and temperatures. The maps provide data that is complementary to the satellite images.

Isn't capturing and processing of satellite data too difficult for kids to do?

Classroom experience indicates otherwise. Children as young as 9 years old have successfully captured and processed satellite images. In many cases, much of the capture procedure can be automated, requiring little intervention. With a little exposure to the technology, most young people have little difficulty with the various data capture and image processing options -- for examples see Appendix A.

These data allow students to process and interpret earth images in ways that correspond to different interests and purposes. For example, one student may process image data to chart coastal currents while another student may use the same data to obtain cloud top temperatures that indicate height and possible rainfall. A third student may include the same data in a "loop" to show how weather patterns move across the continent. Most students enjoy "coloring" the different images to enhance their appearance. With primary data, there are many opportunities for students to interact with the system to develop data processing skills and produce products uniquely their own. They are able to "do science".

Why are these data important to K-16 education in this country?

See Section 2 of this report.

1.3 Alternatives to Direct Readout

Why do we need direct readout? Can't schools simply get satellite images over electronic networks or through a subscription service?

Isn't direct readout just a "niche" technology suitable for certain narrowly defined teaching situations but not broadly applicable to education in this country?

Answers to both these questions are "yes" and "no". Yes, some types of satellite data and other types of environmental information are available over electronic networks and through subscription services, but most satellite images are not. No, this is not just a niche technology. Direct readout has a wide range of applicability to science and technology teaching throughout the K-16 range. However, it does require some commitment to installing and learning to use special equipment. Ultimately, it may be seen as a complement to, not as a substitute for, other sources of environmental data and information.

1.3.1 Other Sources

Weather satellite images and other types of environmental data are available for education from the NOAA/NESDIS, from several universities and university consortia, and from commercial information services (such as CompuServe and AccuWeather).

The most comprehensive data is available via the Internet. For example, the University of Illinois "Weather Machine" (WX) and Purdue University's "Weather Processor" (WXP) are servers intended to provide easy access to weather information for those on the Internet. Those that use this source must have Gopher client software running on their computers and high-resolution display capabilities.

The Purdue Weather Processor handles domestic weather and predictive model data made available by the National Weather Service, and satellite images from the McIDAS Channel of the University of Wisconsin. Meteorologists are the primary audience for these data, but others may view the data in vary degrees of complexity.

One of the most popular directories of the Weather Machine at the University of Illinois is the one called "Images". This directory contain current weather maps and images in GIF-format. The maps "compress" well and may be transmitted as files of about 20 kilobytes in size. However the actual satellite images do not compress well, are much larger, and therefore take much longer to receive.

Unfortunately, few K-12 schools and college classrooms have direct access to the Internet. More commonly, computer modems and telephones allow schools to receive data from secondary sources. These include the "Weather Underground" of the University of Michigan and the UCAR/National Center of Atmospheric Research in Boulder, Colorado. Each of these services provides data and lesson plans for teaching about weather in the classroom. These materials may involve schools in making local weather observations and in electronically sharing and analyzing that data with schools in other areas or regions of the country

The satellite images available from these sources involve delays of several hours to several days. However, in addition to the maps and other statistical information, the networks sometimes transmit high resolution, as well as low resolution images. Using a menu structure, students may select the types of current or historical information they want to download.

1.3.2 Constraints

While electronic networks provides a means for increasing classroom access to weather and other types of environmental data, there are some constraints to this approach.

With a local call most urban schools can link to data providers at a nearby colleges or universities, but calls from rural schools may involve long distance charges. Many school administrators are reluctant to authorize telephones in the classroom, especially telephones with long distance service. They fear that such access will lead to unmonitored and unwarrented use and costs, and set a trend for other classrooms in the school.

Another administrative concern is the open ended and largely unknown costs that may be associated with the continuing delivery of network data. While school administrations are comfortable with making one-time allocations for equipment, open-ended commitments that may require curricula reform and provider reimbursement are seen as expensive in the long term.

Finally, it's no small commitment for a teacher to learn to use computer communication software, to setup accounts, to make electronic connections, and to "navigate" one or more of the various networks in obtaining satellite data. While students also may learn to perform these functions, all network data is not suitable for young people or for classroom access.

Networks are not effective in providing live data in the classroom and therefore, some of the excitement is lost. Raw satellite images files may range in size from 1/2 to over 2 megabytes and take from 5 to 20 minutes to download using standard Modems. In addition, only a small sample of the direct readout data available. While supporting tutorial and lesson-plan information may be delivered by networks, networks do not provide an effective way for students to learn to select and obtain primary scientific satellite data.

2.0 Uses of Direct Readout in Education

Direct readout is, in the words of the late Marshall McLuhan, the "medium" and the "message".

Direct readout promotes environmental understanding from the information contained in the daily satellite images as well as the skills required to obtain that understanding. Students develop workplace skills from the capture and processing of such authentic scientific data. The classroom integration of data capture with scientific analysis creates a strong model of how modern science is conducted in the real-world and how today's scientists go about their business.

Recent studies show that we greatly under estimates the ability of young people to learn and to understand scientific and mathematical concepts. Considerable evidence shows that nearly all students can learn science at higher levels than is currently being achieved [NCSESA, April 1993]. The fact that U.S. students are consistently below the science achievement of many European and East Asian students is symptomatic of our failure to develop effective new methods for motivating and implementing high levels of science learning in our classrooms.

2.1 A Role for Direct Readout

Data captured by direct readout stations complements many science and non-science learning activities and seems to motivate development of mathematics and computer skills. When integrated in an earth and/or physical science curriculum, direct readout provides high levels of student involvement and delivers scientific content. Opportunities for students to capture and analyze "live" earth images focuses on their natural interest in the environment and brings in their enthusiasm for space technology and exploration. Direct readout may be used to illustrate basic concepts of weather and climate, energy and radiation, geography and location, and data and information.

Today, there are at least a couple of thousand satellite direct readout ground stations being used in K-12 schools in the U.S. Probably double that number are being used in schools of other countries, especially in Great Britain, where the collection of weather satellite data has become widely accepted part of the secondary school curriculum.

With the support of the scientific and the educational communities of this country, the number of direct readout stations used in U.S. schools could greatly increase by the year 2000.

2.2 New Science Standards

National Education Goal #4: By the year 2000, U.S. students will be first in science and mathematics achievement.

In 1989 President Bush and the National Governors Association, led by then Governor Bill Clinton, announced unprecedented agreement on the desire to establish national education standards. In 1990 with the acceptance of the idea of national education standards by these leaders and a National Education Goals Panel, the National Committee on Science Education Standards and Assessment (NCSESA) was formed under the auspices of the National Research Council. The education community and many concerned individuals and organizations are now involved in a vigorous effort to develop the science standards that are intended to guide state and local educational institutions in improving and reforming K-12 science education. The standards will provide a broad framework of voluntary goals that are both demanding and attainable for all students and provide a vision of the level of scientific literacy that may be expected of young people to be educated citizens of the 21st Century. These standards are expected to be completed and published by fall 1994.

The American Association for the Advancement of Science (AAAS), the National Council of Teachers of Mathematics, the National Science Foundation, the U.S. Department of Education and many other national and state organizations are united in this need for new educational standards and for the reorganization and restructuring of schools to better deliver education to the student. The AAAS Project 2061 "Science for all Americans" suggests the guidelines listed in Table 2. These guidelines emphasize understanding over content, learning that is useful outside of the classroom, scientific literacy for all students, and interdisciplinary learning. While most educators would agree in principal with these guidelines, there is little in the way of materials or technology available today that helps a teacher implement them. **See Figure 2.**

Figure 2. Students of Greenhills Middle School, Ann Arbor, MI, Using a Direct Readout Station in Their Classroom.

Table 2. Science Education Goals and Objectives

* Promote integration in the three basic scientific fields of study: life science, physical science, and earth and space science;

* Present science in connection with its applications in technology and its implica tions for society;

* Present science in connection with the student's own experiences and interests, frequently using hands-on experiences that are integral to the instruction process;

* Provide students with opportunities to construct the important ideas of science and reflect on historical and cultural perspectives that are then developed in depth, through inquiry and investigation; and

* Provide students with fewer content topics taught in greater depth, as well as teach them to reason logically and evaluate critically the results and conclusions of scientific investigations.

2.3 Obstacles to using Direct Readout

There are several obstacles to using direct readout technology in education . These obstacles relate to the cost and complexity of the technology, the general lack of awareness of the technology,, the lack of tested curriculum materials that incorporate direct readout technology, and the technology phobia of some educators.

2.3.1 Cost and Complexity

For most schools the cost of direct readout equipment is a major obstacle. The hardware and software associated with a basic direct readout station (including antennas, computer, and receiver) can cost upwards to $5000, with peripherals such as printers, CD-ROMs and large monitors extra. Adding the labor cost for installation and training, the expense appears prohibitive to many administrators. While highly motivated teachers have found ways to raise funds for stations and to reduce the hardware and software costs by doing the assembly work themselves, most K-12 teachers have neither the time nor the skills to accomplish this task. While progress has been made in recent years in developing reliable, integrated systems, station installation and set-up still involves considerable effort. Many teachers find local building code requirements and determining a secure location for the placement of the exterior antennas to be the greatest hurdles. For many schools, the use of direct readout technology is inaccessible from a cost and complexity standpoint.

2.3.2 Technology Awareness

Few of the 2.6 million teachers in the 15,500 school districts of this country are aware of the nature and availability of direct readout technology. There are few published materials that provides basic The use of direct readout in the classroom aids in this approach.direct readout information to the education community, and those that exists are too technical for most teachers to comprehend and are often out of date.

For the past 5 years NOAA has helped sponsor an annual three-day "Satellites and Education" conference at West Chester University, Pennsylvania to promote satellite technology in education. This Conference attracts two to three hundred educators, many of whom are affiliated with the amateur radio community. Even within the scientific community, where Landsat and SPOT satellite images are well known, many remote sensing professionals are unaware of direct readout technology and data.

Since 1989, ERIM has implemented the Space Technology Education Program (STEP), directed at promoting direct readout technology for education. STEP has helped to organize a clearinghouse of direct readout information materials and to initiate summer workshops for K-12 teachers at various universities. In 1993 several hundred educators received training at two week workshops conducted by Eastern Michigan University, Weber State University, Johns Hopkins University, and others. These workshops provide teachers with the basic knowledge to install and operate environmental satellite earth stations in their classrooms. In most cases, these workshops are conducted by the natural science faculty, not the education faculty, at these universities. It appears that there are no education schools and colleges, no community colleges, and few universities prepared to teach this technology in pre-service for future teachers.

In June 1993, Weber State University proposed to organize a national network of regional training sites for supporting direct readout in education. In that proposal, seven regional training sites were proposed and available to support this activity. That proposal was rejected by the U.S. Department of Education. Similar proposals to the National Science Foundation (NSF) have met the same fate.

2.3.3 Computer Literacy

The young people of the "Nintendo generation" are facile with video processors (computers), image comprehension, and interactive technologies. However, it appears that many K-12 teachers have neither the computer skills nor access to the technology to make them competent to train others. While many schools have computer labs for teaching computer skills, too often these activities are devorced from the more "academic" subjects. Few math, science, or social studies rooms have computers that help to support the curricula of these subjects.

Many teachers have difficulty in adjusting to a new role as "facilitator" rather than the "authority" in introducing and accessing new sources of information in the classroom. If given a chance, in many cases their students will become more competent in the uses of computer technologies than are the teachers.

2.3.4 Curriculum Materials

If direct readout systems were readily available to computer-literate students and teachers, implementation of the technology would still be slow due to the dearth of curriculum materials that incorporate direct readout in various science, mathematics, and technology lessons. While several sets of lesson plans for math and science teaching have been published, these were prepared by meteorology or technology specialists and are not appropriate for many educators who otherwise may use this technology. These curriculum materials have not found their way into general circulation.

3.0 ERIM Direct Readout Demonstration Station

ERIM has assembled a portable APT-WEFAX earth station designed as a demonstration unit for educators and others.

The ERIM Notebook Satellite Direct Readout station incorporates:

1. off-the-shelf equipment components;
2. portability and easy to use for off-site demonstrations;
3. a full range of data processing and image enhancement options;
4. supporting tutorials, and example images;
5. advanced communications, data exchange, and networking capabilities.

The station has the components listed in Table 3:

Table 3. ERIM Notebook Direct Readout Station

Computer for data storage, display, and processing:
- NEC UltraLite Versa 486/33C
  - 250 Mb removable hard drive
  - Active-matrix VGA, 256 color, 640X480 built-in display and a 600X800 SVGA external display capability
  - 8 Mb Memory card (for total 12 Mb RAM)
  - NiMH battery pack

Docking Station and Receiver for direct readout data capture
- SCSI Adapter (either PCMCIA or parallel)
- PC137 Quorum Receiver card
- GTI Weatherfax scan card
- Replicated notebook computer ports
- Microphone and headphone port

Communications compatibility:
- PCMCIA 14.4 Kbps MODEM card
- PCMCIA Ethernet card

Antennas: Loop Yagi Antenna (for WEFAX reception)
- 1691 MHz to 137 MHz downconverter
- Turnstile APT antenna

Auxiliary Display: NEC 20" SVGA color monitor

DISCLAIMER: Identification of specific commercial brands or products are included for completeness. Neither ERIM nor the U.S. Government recommends or endorses these brands or products as opposed to others that may be available.

Software: DOS, vers 6.0
GTI Weatherfax, vers. 5
ERIM Bird-dog, vers 2.2
Windows, vers 3.1
QuickMenu, vers 1.1a
Mtez (communications)
Orbits (learning about earth orbits)
ERIM Direct Readout Tutorial
Demonstration Images

This station is easy to use and highly portable. The usual 6' dish antenna for receiving WEFAX data is replaced with a portable loop yagi antenna. Once a direct readout image is captured, processed, and saved on the notebook computer while in its docking station (which is connected to the antennas), the computer can be removed from the docking station and set-up at another location for display or demonstration. The computer SVGA color display and large auxiliary monitor allows convenient demonstrations to individuals or groups.

The unattended mode of operation is to continuously display an animated loop of current images that graphically show the past 12 or 24 hours over North America. The oldest image in the loop is removed as the latest images are added to the front of the loop.

A key to direct readout is in its timeliness. Once processed (enhanced, calibrated, superimposed with map or other information) these image data may be quickly transmitted to other on-line locations and combine with other data in environmental models. The 14.4K baud modem and the Ethernet card provide easy access to a large number of databases and data processing functions.

4.0 System Enhancements

ERIM has made several software enhancements to improve the utility of this direct readout station for demonstration and further system development. These enhancements improve both technology demonstrations and classroom applications.

4.1 Quick-Menu Start-up Screen
This station contains a large number of program and image files. To simplify access to these programs and files, ERIM has developed a multilayer menu structure. The start-up menu shows four buttons: 1) "About direct readout", 2) "Applications to education", 3) "Example images", and 4) "Just do it!". Any button on the submenu may be selected by pointing and clicking with the computer mouse. Each of these buttons leads to a submenu with four to eight additional selections relating to that topic. Each button on the submenu activates a different program that supports direct readout activities in classroom. The "Just do it!" menu calls up the main data capture and processing program (Weatherfax). While only one of the programs (Weatherfax) is directly concerned with image data capture, enhancement, and display, the other programs are intended to contribute to the educational use of this technology.

Not all of the example images are APT and WEFAX images. Some high-resolution HRPT and Stretched-VISSR have been included to demonstrate the nature of such data. Although these are not received by this APT/WEFAX direct readout station, the images may be processed by this station. (High resolution images may be available to classrooms over electronic networks or they may be ordered from NOAA or USGS directly.)

4.2 Software Integration
Half a dozen different programs are necessary to provide a full range of direct readout functions for the classroom. For ease of use, these functions may be combined into a single program. For example ERIM's Bird-dog program, used to track satellites and predict their arrival times, is now integrated within the data capture program. Under this program ERIM is working to integrate other more advanced functions such that the programs may work together.

4.3 Educator-friendly documentation
As part of this program, ERIM has taken existing technical manuals and teacher guides and edited and rewritten them to make them more comprehensible to teachers and other non-technical users. These guides and manuals include the "STEP Teacher's Guide to Using Satellite Direct Readout in the Classroom".

5.0 Opportunities and Recommendations

Various opportunities are available to enhance the use of direct readout in education and in other applications. These opportunities range from making better use of existing hardware assets to supporting educator training and testing new curriculum materials. These opportunities may overcome some of the obstacles identified in Section 2.3.

5.1. Using older PCs

Of the more than 100 million operational personal computers (PCs) in use today, nearly 40% have Intel 80286 central processors. Many of these systems are owned by the national, state and local governments. Others are used by businesses and educational institutions. These 286 systems are considered obsolete by today's standards and are no longer supported by their original vendors. They have either been replaced or are slated for replacement with more advanced machines in the near future. Many are being donated to schools and other educational institutions for tax purposes and other purposes.

Such systems provide the basis for capable direct readout stations for schools. With the addition of a receiver card and antenna, most of these 286 systems would work as basic dedicated ground stations. Approximately, one thousand dollars worth of upgrading would be necessary. Existing 286 AT-class PCs running at 10 Mhz clock speeds (and having 640K of RAM, one floppy drive, a parallel port, and a VGA display) are sufficient for the basic satellite tracking, data capture and image processing functions. Because the image files captured by a station are fairly large (0.5-2.5 megabytes), its most desirable to have a 40 megabyte hard drive or preferably greater.

To incorporate some of the more advanced windowing and CD-ROM educational software in a direct readout station, the 286 central processor chip or mother-board would have to be replaced with a 386 or, preferably, a 486 system and additional active memory.

5.2 Toward a low-cost system

While the technology for creating a very low-cost direct readout station exists, such systems are not commercially available. By low-cost we mean a system to collect environmental satellite data for under $2000.

In Table 4 (below) we have specified an example of a low cost system. In addition to a standard PC and an external receiver, such as the Vanguard WEPIX 2000-B, this system uses a stand-alone satellite FAX demodulator. The demodulator plugs directly into the parallel printer port of any IBM-compatible personal computer and converts the direct readout signals to a digital input -- providing portability and eliminating the need for internal computer modifications.

While lacking some of the advanced image processing capabilities and other functions of the more costly systems, this system provides the basic APT and WEFAX data capture and display functions.

The station is the most basic entry level system. It's applicable to schools that already have a PC and are interested with obtaining new satellite images each day. It may be characterized as the "Volkswagon" version of a direct readout station and is appropriate at the primary grades. Admittedly, it doesn't provide most of the data enhancement functions, such as coloring, temperature calibration, and animating multiple images, which make direct readout interesting to students in intermediate and secondary schools, but it does provide for the real time capture and display of APT and WEFAX data -- and the total price is less than $ 1800. For some schools, no more advanced system than this may be needed.

Table 4: ERIM Proposed Low-cost Direct Readout System

Computer: 80286 AT-class with VGA B&W monitor (usually free to schools)

Receiver (external): Vanguard WEPIX 2000-B (est. $300)

Scan demodulator: WSH WeatherFAX assembled ($250)

Antennas: Radio Shack FM antenna ($79)
Loop-yagi ($300)
WEFAX Down Converter ($650)

Misc. cables and hardware ($200)

5.3 Suggestions for new systems

Given the relatively low cost of the available technology and its compatibility with other hardware/ software platforms, there are a range of systems that could be created which could contribute to educational activities. Each system would incorporate capabilities which complement the direct readout data capture and provide products that are tailored to specific applications. Each configuration contributes in a different way to education.

5.3.1 A weather station version

A direct readout station could be optimized for gathering weather-related data, both locally by monitoring the environment with sensors and probes, and remotely through direct readout. A computer may be programmed to automatically record and calibrate local weather data obtained with environmental sensors (probes) such as air temperature, humidity, precipitation, sunshine and other meteorological variables. These observations may be compared with measurements made by other schools and with concurrent direct readout images. Such a weather station could be used by a students for issuing weather reports to classes in their schools. In addition a weather station could be used for annotating and printing satellite images as weather maps. (Noted that IBM currently markets a weather station computer to K-12 schools, but it doesn't have direct readout capability.)

Capable systems in this price range would make direct readout accessible to most K-12 schools, even in this era limited school budgets for scientific equipment.

5.3.2 A multimedia version.

Large numbers of high-quality satellite images, collected by the U.S. Space Program over the past several of decades, are available through NASA and other organizations for classroom use. These images, recorded in digital form, may best be distributed on CD-ROMs. Direct readout provides opportunities for students to display and enhancing these images; student projects can involve comparing new "live" images with these historical images recorded on CD-ROMs.

Several such image compilations are currently available from both public and private organizations. Through projects sponsored by USGS ("JEDI"), NASA, and the Canadian Remote Sensing Agency ("Geoscope"), extensive archives of high-quality remote sensing and geophysical data are available to classroom teachers. Having a direct readout capability allows these images to be compared and displayed.

There are opportunities for integrating video and animated video sequences to tutorial programs that accompany direct readout stations. For example, animated "loops" of historical hurricanes, severe storms, forest fires, ocean currents would convey some of the dynamic qualities of earth system science. Both technical and social (TV footage) data could be combined with lesson plan information about the 1992 Hurricane Andrew, the 1993 Mississippi Floods, or other newsworthy events -- including sound.

5.3.3 A GIS version

Direct readout provides geographic data in standard digital formats (TIFF, GIF, PCX, etc.). These data provide ready made inputs to PC-based Geographic Information Systems (GIS). Combining direct readout with GIS provides a platform for learning many geographical principles, such as scale, direction, and orientation, and may be used for conducting student research. For example, by combining daily direct readout images with GIS-derived local terrain and transportation maps, information on local hazards or populations at risk may be identified. Flooding, snow cover, ice on lakes and rivers, and vegetation conditions may be combined with GIS maps to assess transportation routes, crop losses, or other impacts. The damage of hurricanes may be anticipated by looking at maps of the built environments along the coasts effected. The use of direct readout with GIS can be applied to student and faculty research projects at secondary and college levels.

5.3.4 A Kiosk version

Museums, science centers, aquaria, and public parks maintain visitor displays that are educational and informative. An automated version of a direct readout station with continuously updating images can easily be incorporated into a kiosk containing a large computer screen or multiple screens. Such a kiosk could display weather information for visitors for different locations at the touch of the screen.

5.3.5 A Macintosh version

Although Apple Macintosh computers are widely used in K-12 education, especially at the lower levels, few direct readout capabilities and supporting materials have been developed for this platform. There are significant opportunities to expand the uses of direct readout technologies in education by developing further support for the Macintosh computer.

5.4 Software Integration

A number direct readout image processing and data integration functions that can be made more intuitive and routine with further software development.

5.5 New standards and guidelines

The effective promotion of direct readout must tie its output to specific teaching outcomes. Most teachers will seek to use those technologies that offer of a clear and positive correlation. In other words, while direct readout may supply an interesting and diverse images, it must as an appropriate tool for motivation math, science, technology and other types of learning, the pedagogical results of direct readout must be related to different teaching methods.

5.6 A STEP-led education consortium

Teachers can not do it alone. Successful examples of the installation and use of direct readout in K-12 schools usually involve the support of outside organizations such as STEP. Working through local universities and community colleges, STEP can provide technical and instructional support to teachers if it is funded to do so.

For the past two years under STEP, concerned educators and vendors met to discuss ways to advance the utilization of direct readout in education. In June 1992, twenty-six educators met in Ann Arbor and, among other things, agreed to form an informal consortium of individuals and institutions to exchange plans and information to promote direct readout in education. One year later, a majority of educators agreed to the need for a more formal structure. Due to funding constraints, this new organization has yet to be organized. However, such a consortium could promote direct readout both within education and represent the interests of education to the space science community.

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Appendix A: Examples of Student Direct Readout Projects

HYLTON HIGH SCHOOL
WOODBRIDGE, VIRGINIA

GLOBAL CHANGE ISSUE: *Changes in the frequency of severe storms and hurricanes are an indicator of climate change.*

PROJECT: Demonstrate the physical and social impacts of Hurricane Andrew.

STUDENT: Jacqueline Fraser

TEACHER: Chuck Drake

PRINCIPAL: Wayne Mallard

BACKGROUND

By hurricane standards, Andrew was not a major storm. There have been greater hurricanes. Yet its impacts were many and were the most costly of any single natural disaster in history. Early warnings of the approach of hurricanes, such as Andrew, have resulted in lower losses of life over the years, but such warnings cannot protect the natural environment and human property from the enormous physical damage. This project explores the many physical and social impacts of Hurricane Andrew as illustrative of the complex multidisciplinary nature of such weather-related events.

PROJECT DESCRIPTION

HYPOTHESIS

Hurricanes, such as Andrew, concentrate huge amounts of energy in relatively small geographical areas and cause impacts that affect many different aspects of the human and natural environment. Its study requires a multidisciplinary approach.

METHODOLOGY

We carried out a number of activities that contributed to our understanding of the physical and social impacts of Hurricane Andrew. These studies included calculations of Andrew's size and energy content, mapping its rate and direction of movement, and assessing its destruction to environments in southern Florida and central Louisiana. These studies required applications of concepts from mathematics, physics, geography, oceanography, ecology, economics, history, and information technologies.

Our studies included preparing and animating a time series of weather satellite images to map the direction and rate of Hurricane Andrew's movement. We found its speed and direction to vary with time, making predictions of its precise landfall uncertain.

Using weather satellite images obtained over a five-day period, we were able to track Hurricane Andrew and determine its speed and direction. Using a mathematical method provided to us by Professor Kerry Emanuel at MIT's Center for Meteorology and Physical Oceanography, we calculated that the total power of Hurricane Andrew was 1,360 billion watts, equivalent to the more than half of the total electrical consumption of the United States in a year.

From the historical record we learned that with the improvements in early warning, the number of deaths as a result of hurricanes has gone down dramatically in the United States, but the economic losses have increased—culminating in the $30 billion losses from Hurricane Andrew.

93-22504.10

Weather facsimile (WEFAX) image of Hurricane Andrew obtained by Hylton High School students on 25 August 1992.

CONCLUSIONS

Understanding hurricanes and their impacts involves the use of knowledge and skills from different scientific, technological, and social disciplines.

TEACHER'S COMMENTS—

Newly emerging National Standards for math and science education stress the importance of integrating science concepts with technology and social science subjects. The use of satellite direct readout provides a classroom mechanism that promotes that integrated multidisciplinary approach.

Linganore High School
Frederick, Maryland

Global Change Issue: *Understanding linkages between oceanic and atmospheric systems.*

Project: A study of ocean currents and wind currents on storm development over the Atlantic Ocean.

Student: Steven Emrick, Senior

Teacher: Dale Peters

Principal: Hank Bohlander

Background

This project studies one of the most important weather makers on this planet—the oceans. We focused on the Atlantic Ocean and its currents. Four main currents occur in the North Atlantic between the United States and Europe. Three of these currents are of concern for this study: the Gulf Stream (extending north from the Bahamas along the eastern coast of the United States and then east into the North Atlantic), the Canary Current (extending south from the coast of Europe to northwest Africa), and the North Equatorial Current (making the long run from the coast of West Africa west to the Caribbean).

These currents are formed by trade winds. The trade winds run in a clockwise pattern from west to east in the northern part of the North Atlantic, and east to west near the equator. How do the winds and ocean currents affect the development of storms? Do they affect the pattern and movement of the storms?

Project Description

Hypothesis

The location of clouds, and therefore storminess over the Atlantic Ocean, is asymmetrical and concentrated over major ocean currents.

Methodology

We examined four sets of satellite images of the Atlantic Ocean to identify areas of cloudiness and the relationship of clouds with currents. We used Meteosat-3 images of the North Atlantic Ocean and studied the cloud patterns on consecutive days. The first analysis is for 9/21/93 to 9/22/93, while the second is for 9/27/93 to 9/28/93. With these images, it was possible to observe the patterns of cloud movement and the changing intensity of storm systems.

For example, in the image that covered Central America and Mexico, we observed intense cloud cover and probably heavy storms. These storms are in the same area as tropical rain forests. This area is called the Intertropical Convergence Zone (ICZ)—winds "converge" in this area. Easterly winds come from across the Atlantic and southerly winds come from the South Pacific and up the western coast of South America. These winds carry moisture from the oceans in this area, which combine with the warm tropical air to make a perfect environment for heavy thunderstorms to develop later in the day, when the air is sufficiently heated. The repeated appearance of these enormous clouds provides evidence that the winds in these areas play a key role in the intense rainfall development.

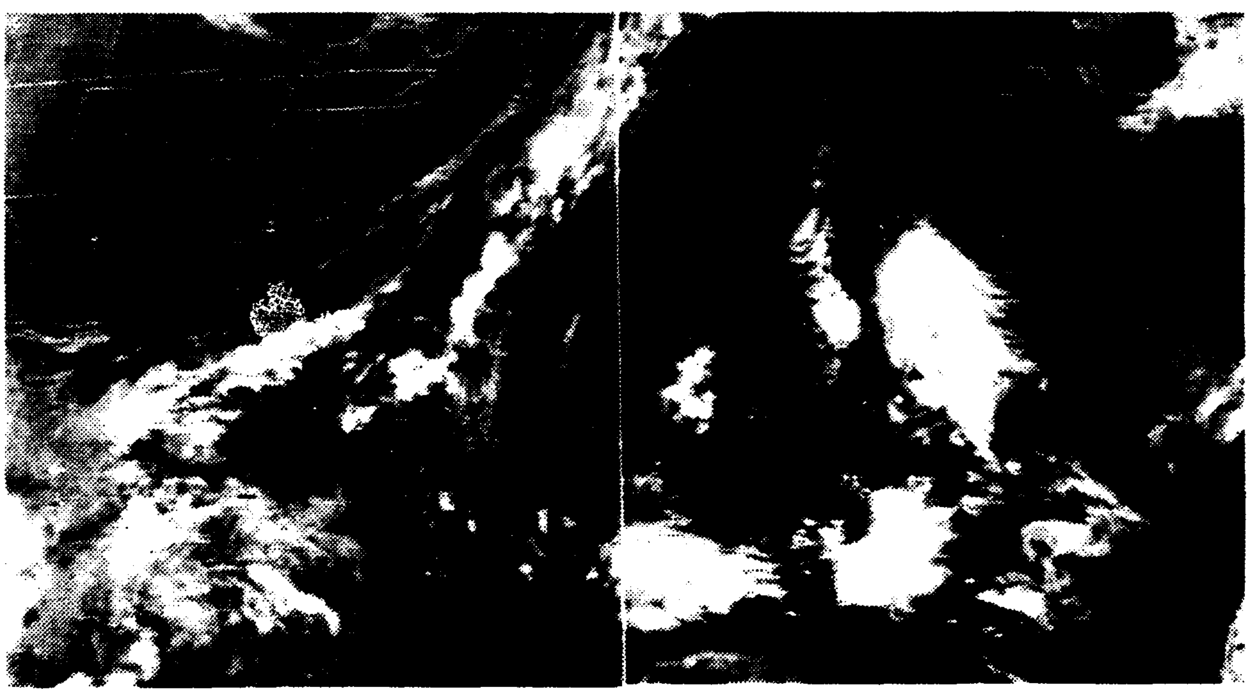
93-22504.6

The prominent ocean current near Europe is the Canary current, running south to the northwest coast of Africa. From images labeled 9/21 and 9/22 vertical cloud coverage is evident and cloud location coincides almost exactly with the Canary Current. This is evidence that ocean currents affect cloud cover.

Thus, we have evidence, but not yet proof, that ocean and wind currents have a positive effect on storm development. Perhaps a lack of ocean and wind currents have a negative effect. We examined an area of the Atlantic in which the wind and ocean currents are reduced to a bare minimum. This area is between the three ocean currents, about halfway between the U.S. and Europe. It is called the Sargasso Sea and is associated with lots of floating seaweed and algae. In all of the satellite images, there is little evidence of heavy cloud cover over the Sargasso Sea. The farther you move in each direction away from the Sargasso Sea, the more likely there will be heavier cloud cover.

Conclusions

There is evidence from these pictures that storms develop where wind and ocean currents are strong; they do not flourish under the opposite circumstances. (It would be interesting to perform a similar exercise for the North Pacific Ocean since the wind and ocean current patterns are basically the same.)



Weather facsimile (WEFAX) images of Atlantic Ocean obtained by students at Linganore High School on 28 September 1993.

Linganore High School
Frederick, Maryland

Global Change Issue: *Understanding linkages between oceanic and atmospheric systems.*

Project: A study of ocean currents and wind currents on storm development over the Atlantic Ocean.

Student: Steven Emrick, Senior

Teacher: Dale Peters

Principal: Hank Bohlander

Background

This project studies one of the most important weather makers on this planet—the oceans. We focused on the Atlantic Ocean and its currents. Four main currents occur in the North Atlantic between the United States and Europe. Three of these currents are of concern for this study: the Gulf Stream (extending north from the Bahamas along the eastern coast of the United States and then east into the North Atlantic), the Canary Current (extending south from the coast of Europe to northwest Africa), and the North Equatorial Current (making the long run from the coast of West Africa west to the Caribbean).

These currents are formed by trade winds. The trade winds run in a clockwise pattern from west to east in the northern part of the North Atlantic, and east to west near the equator. How do the winds and ocean currents affect the development of storms? Do they affect the pattern and movement of the storms?

Project Description

Hypothesis

The location of clouds, and therefore storminess over the Atlantic Ocean, is asymmetrical and concentrated over major ocean currents.

Methodology

We examined four sets of satellite images of the Atlantic Ocean to identify areas of cloudiness and the relationship of clouds with currents. We used Meteosat-3 images of the North Atlantic Ocean and studied the cloud patterns on consecutive days. The first analysis is for 9/21/93 to 9/22/93, while the second is for 9/27/93 to 9/28/93. With these images, it was possible to observe the patterns of cloud movement and the changing intensity of storm systems.

For example, in the image that covered Central America and Mexico, we observed intense cloud cover and probably heavy storms. These storms are in the same area as tropical rain forests. This area is called the Intertropical Convergence Zone (ICZ)—winds "converge" in this area. Easterly winds come from across the Atlantic and southerly winds come from the South Pacific and up the western coast of South America. These winds carry moisture from the oceans in this area, which combine with the warm tropical air to make a perfect environment for heavy thunderstorms to develop later in the day, when the air is sufficiently heated. The repeated appearance of these enormous clouds provides evidence that the winds in these areas play a key role in the intense rainfall development.

93-22504.6

MOUNDRIDGE HIGH SCHOOL
MOUNDRIDGE, KANSAS

GLOBAL CHANGE ISSUE: *Define the observable indicators of weather which allow the monitoring of changes in climate over time.*

PROJECT: Compare visible and thermal infrared weather facsimile (WEFAX) images to help identify basic cloud types.

STUDENT: Brad Jantz, Senior

TEACHER: Joe Zerger

PRINCIPAL: Bill Nelson

BACKGROUND

Environmental satellites were invented in the early 1960s for the purpose of providing meteorologists with accurate and timely pictures of cloud patterns and their movements. From such information weather predictions are made. This project verifies our ability to identify the different types of clouds that provide current weather information and allow accurate predictions to be made.

PROJECT DESCRIPTION

HYPOTHESIS

Comparisons of visible and thermal WEFAX images obtained from the geostationary Meteosat 3 satellite will allow correct identification of nine principal types of clouds.

METHODOLOGY

Obtain and store visible Meteosat images of the United States at 11:50 a.m. each day and thermal infrared images at 12:10 p.m. each day. Compare these two images by animating them in order to easily compare their similarities and differences.

Special note is taken of the region near and around Kansas. Image pixels that are bright (in the visible and the infrared) are highlighted with red to emphasize the locations of clouds.

Both the visible and the infrared images are printed out. On these hard copies, we make notes and label the cloud types, frontal systems, and areas of potential storms. Any short-range local forecast information is added, if it is available.

At approximately noon three or four Polaroid photos are taken of the sky in carefully noted directions. These are labeled and then used as "ground truth" to aid in our interpretation of cloud types and in determining the accuracy of the cloud type labels. All these data are compiled on a daily basis. The satellite images are saved on floppy discs for later reference.

The following cloud types were identified:

	VIS Image	IR Image	Ground
Upper level:			
Cirrus (Ci)	grey	white	veil-like
Cirrocumulus (Cc)	streaks		small puffs
Cirrostratus (Cs)	light	bright	layers
Mid-level:			
Altocumulus (Ac)	bright	light	puffy cells
Altostratus (As)	bright	light	thick, grey
Cumulonimbus	bright	light	thunderheads
Low-level:			
Cumulus (Cu)	light	grey	open puffs
Stratocumulus (Sc)	light	grey	lumpy, grey
Stratus (S)	light	grey	low, disperse

Visible and infrared images of central U.S. showing different cloud types. These weather facsimile (WEFAX) images were obtained by students at Moundridge High School, Kansas.

CONCLUSION

We have seen that it is possible to identify cloud types from space and from the ground. However, weather prediction is still difficult and often requires more than just a sky view, including the one from space.

TEACHER'S COMMENTS—

Example: On 13 September a strong frontal system passed over central Kansas. Seven visible images were taken at hourly intervals and were then animated. This procedure provided valuable information concerning the movement of the system: its direction, speed, and changes in intensity.

White County Middle School
Cleveland, Georgia

Global Change Issue: *To determine the nature of global climate change, measurements of the earth's temperature must be comparable and accurate.*

Project: Evaluation of terrain temperatures as observed from the ground and from weather satellites.

Student: Seth Steele, 8th Grade

Teacher: Richard Behrens

Principal: William Jenkins

Background

Thermal infrared satellite images can be calibrated to provide temperature measurements of terrain surfaces. But how well do they represent true ground temperatures? Automatic picture transmission (APT) provides low resolution images (one pixel covers at least 4 square kilometers). What does it mean to obtain a single temperature measurement from the surface of such a large area?

Project Description

Hypothesis

The temperatures obtained from a calibrated APT infrared image will be within a range of plus or minus 5 degrees from true ground temperature.

Methodology

We are capturing NOAA-10, NOAA-11, and NOAA-12 infrared images for both morning and evening passes. After saving each image, we screen the data for Atlantic and Gulf coast images with no clouds. We also obtain coastal temperature data via modem from NOAA/Weather Brief. All of the temperature data (both satellite and ground based) are then averaged (from five or six observations) and compared by location to determine whether they fall within 5 degrees of each other. The two data sets are being statistically compared to determine their degree of correlation. (It is assumed that the NOAA/Weather Brief temperatures are accurate for their locations.)

This study was conducted for coastal areas so that the land–water boundaries could be used to determine accurate locations for the temperature measurements.

Conclusion

We discovered that there are many reasons that the comparison of temperature measurements obtained from different methods is difficult. The main limitations in using satellite temperature data are: moisture in the air (water vapor), determining precise geographical locations, and uncertainties in the radiometric temperature calibration. Preliminary results indicate that the morning temperature measurements were more accurate and fell within the plus or minus 5 degree temperature range.

93-22594.2

Infrared image of the U.S. east coast showing temperature patterns on 9 October 1993.

Teacher's Comments—

Educational Goals

The goal of this activity is to provide students with the opportunity to test and verify an important hypothesis that at first glance looks relatively straightforward and easy—testing the accuracy of temperature measurements. In reality, this is a complex scientific undertaking, involving understanding the different ways in which temperature can be measured, the many sources of possible error associated with each temperature measurement (including instrumentation), and the problems of scale when comparing radiometric measurements with sensible heat measurements. This activity involves problem solving and the use of scientific reasoning skills. It is analogous to current efforts to reconcile conflicting satellite and ground temperature measurements being obtained by different U.S. Global Change Research Program researchers.

WHITE COUNTY MIDDLE SCHOOL
CLEVELAND, GEORGIA

GLOBAL CHANGE ISSUE: *To determine the nature of global climate change, measurements of the earth's temperature must be comparable and accurate.*

PROJECT: Evaluation of terrain temperatures as observed from the ground and from weather satellites.

STUDENT: Seth Steele, 8th Grade

TEACHER: Richard Behrens

PRINCIPAL: William Jenkins

BACKGROUND

Thermal infrared satellite images can be calibrated to provide temperature measurements of terrain surfaces. But how well do they represent true ground temperatures? Automatic picture transmission (APT) provides low resolution images (one pixel covers at least 4 square kilometers). What does it mean to obtain a single temperature measurement from the surface of such a large area?

PROJECT DESCRIPTION

HYPOTHESIS

The temperatures obtained from a calibrated APT infrared image will be within a range of plus or minus 5 degrees from true ground temperature.

METHODOLOGY

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CONCLUSION

We discovered that there are many reasons that the comparison of temperature measurements obtained from different methods is difficult. The main limitations in using satellite temperature data are: moisture in the air (water vapor), determining precise geographical locations, and uncertainties in the radiometric temperature calibration. Preliminary results indicate that the morning temperature measurements were more accurate and fell within the plus or minus 5 degree temperature range.

93-22594.2

Williamsport High School
Williamsport, Maryland

Global Change Issue: *Industrial activity can cause atmospheric pollution that may have long-term consequences on the natural environment.*

Project: Can sources of acid rain pollution be located by the movement of weather fronts?

Students: Shannon Aleshire, Danielie Hammersla, Cristel Reed, and Shelley Robertson, 11th grade

Teacher: Katherine Richter, with special thanks to Charlotte Trout for her time and advice.

Principal: Herb Hardin

Background

Acids form when certain atmospheric gases (primarily carbon dioxide, sulfur dioxide, and nitrogen oxides) come in contact with water in the atmosphere or on the ground and are chemically converted to acidic substances. Although rain is naturally slightly acidic, human activities can make it more more acidic. Acid rain is a serious problem because of its effects on plants and soils in the United States.

Project Description

Hypothesis

Because the United States is in the zone of prevailing westerly winds, sources of acid rain precursors (coal-burning industries) will be found west of areas with acid rain damage.

Methodology

To begin the project, we researched the topic of acid rain. We discovered which chemicals are most responsible for acid rain (carbon dioxide, sulfur dioxide, and nitrogen oxides) and which types of human activity are putting those chemicals into the atmosphere (industrial and energy-generating facilities that burn fossil fuels—mainly coal—and increased transportation). We learned which environmental problems acid rain can cause and some ways that our society can reduce the amount of acid rain pollution. Also, we are doing a meteorology unit in our Earth science classes, which gave us information about the water cycle and weather fronts. We also collected data on the location of coal-burning industries and the tons per square mile of acid rain precursors produced. This information was provided by Potomac Edison who sent us a listing by state of where coal-fired power plants are located. We plotted this data onto a map of the United States and used all of it to develop our problem and hypothesis.

Using our direct readout weather station, we tracked the movement of weather fronts across the eastern half of North America. We collected visible automatic picture transmission (APT) images from polar-orbiting satellites over the periods of September 22–24, 1993, and September 27–28, 1993, during the morning and afternoon. This allowed us to verify a consistent west-to-east movement of the fronts. We were also trying to determine if the typical movement of the fronts could be responsible for transboundary acid rain pollution. For example, Canada has complained that industries in the United States can be held responsible for acid rain problems in that country. Along with our computer images we collected a series of weather maps from the newspaper, as well as data on the pH range of precipitation. We also built a

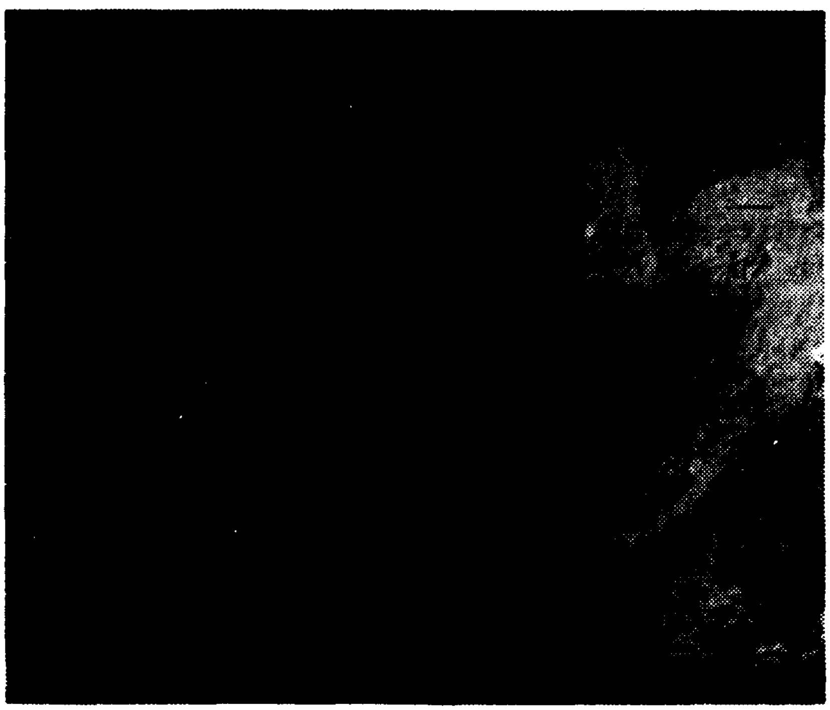
93-22504.8

working model of our research project which shows the water cycle (with sources of humidity and precipitation), combustion (burning coal), and a wind source (a fan, which demonstrates how acid rains can be moved).

CONCLUSION:

Using maps, we can show locations where acid rain precursors are produced and locations where there has been acid rain pollution and damage. We found relatively insignificant amounts of acid rain precursors and damage in the far-west and southwest United States. There was a definite pattern in the northeast and midwest industrial states. Specifically, we found that east of the Great Lakes region was the center of lowest pH values (<5—the range of acid rain). We created an acetate map overlay so that we could compare the maps to see evidence that the sources of acid rain precursors (coal-burning industries) are, in fact, west of areas with acid rain damage. We also believe that transboundary pollution (between the United States and Canada) is possible, the movement of weather fronts we observed would support this, but is very difficult to prove.

We were able to find evidence that acid rain pollution is located downwind (east) of industrial sources (coal-burning industries). However, acid rain pollution and damage is obviously a very broad topic and there are many variables to consider. Coal-burning industry is just one of the variables. Increased human activities, such as transportation, is another important variable. One of the major limitations was that our project focused on the northeastern United States. This area contains many urban areas where there is much greater human activity that can also contribute to acid rain pollution. Another limitation of our study was difficulty in finding data on areas where there is acid rain damage. A database of this information would be a very useful resource.



Visible APT image showing storm clouds carrying acid rain over northeastern United States obtained by students of Williamsport High School.

Williamsport High School
Williamsport, Maryland

Global Change Issue: *Industrial activity can cause atmospheric pollution that may have long-term consequences on the natural environment.*

Project: Can sources of acid rain pollution be located by the movement of weather fronts?

Students: Shannon Aleshire, Danielle Hammersla, Cristel Reed, and Shelley Robertson, 11th grade

Teacher: Katherine Richter, with special thanks to Charlotte Trout for her time and advice.

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Background

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CHAMBERBURG AREA HIGH SCHOOL
CHAMBERSBURG, PA

(from WeatherSat Ink Journal, Summer 1992)

ISSUE: Measuring Sea Surface Temperature by Satellite

PROJECT: Compare Ground Truth from remote reading buoys and IR temperatures from US TIROS satellite Infra-Red APT

STUDENT: Jodie McKee and Kelly Nutter

TEACHER: R. Joe Summers, Science Department

BACKGROUND

Environmental satellite sensors allow the earth's vast oceans to be monitored on a daily basis. In particular, thermal infrared data for making sea surface temperature measurements may be received from satellites by relatively low cost ground stations. This study was conducted to assess the quality and reliability of sea surface temperture measurements obtained from the polar orbiting NOAA satellites The satellite-derived data were systematically compared to "sea truth" temperatures obtained from remote ocean bouys operated by NOAA.

METHODOLOGY

Sea truth temperatrues were collected using a computer bulletin board operated by the National Weather Service (NWS) in Portland, Maine. The bulletin board provided hourly data from thirteen remote bouys located in the Atlantic Ocean along the eastern coast of the United States. These data was collected from the computer bulletin board each morning over a 62 day period, starting on October 22 and ending Februay 4, 1991. \

On the same days, NOAA infrared satellite pictures of the the western Atlantic Ocean were recieved using the satellite earth station at Chambersburg Area Senior High School. Images received from the NOAA satellites at this ground station (39:56N, 77:39W) extended from Canada to Cuba. All the images for this study were calibrated using the AVHRR calibration program of Weathert Trac (WeatherTrac). The images showed the eastern coastline of the United States, extending from Cape Hatteras to the Sea Islands of Georgia.

...The images used in this study were primarily from NOAA 10 and NOAA 11, which transmitted images during the morning hours. A few afternoon infrared images from NOAA 11 were also used.

A map was prepared showing the locations of the NOAA bouys from which hourly ocean temperatures were obtained. The locations of these bouys on the infrared satellite images were then approximated. Using the temperature calibration program (a different calibration for each satellite), the mean temperatures at the times of the satellite passes where obtained. This could only be done for cloud free areas. The areas of this study included were the following bouys at their respective locations: 41009

(28.5N, 80.2W), 41010 (28.9N, 78.5W), SAUFI (29.9N, 81.3W), 41008 (30.7N, 81.1W), FPSN& (33.5N, 77.6W), 44009 (38.4N, 74.7W).

From October 14 through February 4, thirty-three usable images were received, that is, cloud free for the bouy locations. The temperature data obtained from the satellite infra-red images was labeled SST. The data received from the bulletin board was labeled BOUY. The SST temperatures were then compared statistically to the tsea truth emperature information received from the computer bulletin board. After 62 days, a regression analysis test was run to compare the SST and BOUY data.

CONCLUSION

The results of the regression analysis, have an r value of .922, which indicates that the satellite SST temperatures were closely correlated with the observed temperature readings. This result gave us confidence that the satellite data is a reliable measure of actual ocean surface temperature as recorded by the NOAA buoys. This result allows confidence in the use of satellite SST data for obtaining temperatures in parts of the Atlantic or in other oceans where no bouy measurements are available.